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Energy consumption optimization for thermal energy harvester applications

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Anotation:
This paper demonstrates the concept of node consumption reduction for IoT applications. The main emphasis is placed on the autonomy of the whole device, which must be independent of external power supply. That is why energy harvesting based on temperature principle is used for power supply. One of the parameters monitored is the service uptime. The concept of intelligent control of the individual parts of the equipment leads to significant energy savings. This control requires the use of low power components, but only their appropriate connection and mutual monitoring of their operating modes leads to the desired savings.
This algorithm can be adapted to the needs of IoT nodes focused on real-time performance applications or the process tracking slow low power applications. This concept will ultimately be adapted to a wireless node for monitoring position and temperature for use in medical applications to monitor the patient's position on the bed or position while moving.

INTRODUCTION

The aim was to design the device transform electricity from thermal energy for low power applications allowing reading of sensor data and sending data via wireless network to the parent device (phone, tablet, PC). Emphasis was placed on achieving the lowest possible consumption, in order to be able to be powered from the battery, possibly the energy harvester This application is intended for medical purposes, the device will be placed on the patient's body and the temperature generator (Peltier cell) will be powered from the temperature difference between his / her body and the surroundings. The integrated accelerometer and thermometer will measure this data at regular intervals and send it via Bluetooth LE to the collection point, which will be connected to the internet and, after analyzing the status, will eventually send SMS or alert the patient's abnormal behavior.

Fig. 1 shows a block connection of the whole device. The input generator is connected to the power management module, which collects the accumulated energy and converts it to a suitable voltage. The collected energy is stored in a 1F supercapacitor. Main microcontroller has accelerometer and thermometer connected to its inputs. The output is a Bluetooth module for communication with the remote unit. The operating mode of the processor is usually responsible for the highest share of the consumption of the whole device. The proposed concept works on the principle of chained control, where only those peripherals that are required to deliver data are active at the moment, this allows to set the non-active devices into sleep mode. This chained control is driven by smart interrupt triggering. The operating mode of the individual parts of the device can be controlled centrally by a microcontroller. The adaptation of this method achieves a 60% savings over conventional wiring and control. Instead of analog sensors will be in the next prototypes purely digital sensors used which will lead to another decrease in power consumption (more than 95%).

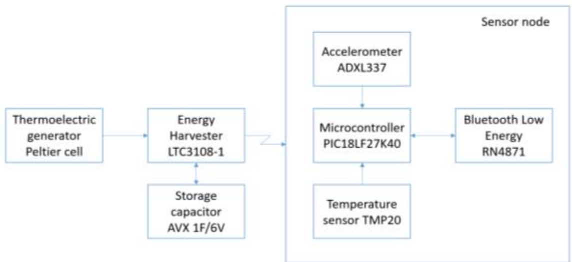

Fig..1 Autonomous node with energy harvesting source

REALISATION

The Peltier cell was chosen as a converter of thermal energy to electric. For the purpose of collecting energy and converting it to the voltage level for the application power, the DC/DC boost converter LTC3108-1 was selected. The catalogue connection of this converter has been used. In the recommended connection it can boost the input voltage in the range of 20 mV to 500 mV up to the desired level of 3 V and can control the storage of the generated electrical charge for the period of bridging the power generator outage.
At an ambient temperature of about 25 degrees Celsius and by touching with human hand the Peltier cell with dimensions 40 mm x 40 mm, it generates a voltage with a value of tens of mV (about 30 – 100 mV) depending on the temperature difference on both sides of the cell.

An application using a temperature sensor and a three-axis accelerometer was chosen for the demonstration. This combination of sensors allows to measure the temperature of the human body, the position of sensors in space and acceleration (thus allowing to detect e.g. fall or generally rapid movements). For data transfer, the application is equipped with Bluetooth Low Energy module.

TESTING

The Peltier cell (its real output power ist shown on Fig.2), combined with the harvester, generates a 3 Volts, but with a very low output current.

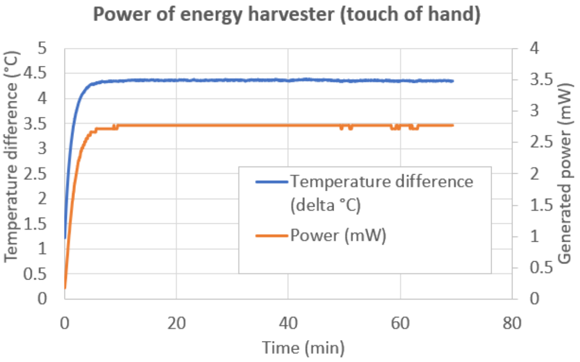

Fig.2 Real power of Peltrier cell

There are few possibilities how to increase the power outcome:
a) Combining multiple Peltier cells
b) More powerful electric power generator
c) More powerful heat source (radiator, motor/car exhaust, fridge evaporator)

The goal was to reduce application consumption to a minimum. Due to the use of analogue temperature and acceleration sensors, it was necessary to use the AD transfer control microcontroller, which increased the consumption by approximately 160 uA. The analogue sensors themselves also have relatively high consumption (see Table 1).

Tab. 1: Power consumption

Parts	*Parameters*	*Note*
µC	~ 300 µA	Active mode
Accelerometer	~ 300 µA	
Temperature	~ 4 µA	
Bluetooth	~ 300-2300 µA	Send on/off

However, the BLE module has the highest consumption. Due to its high consumption especially in active mode (2300 µA), reducing the consumption of other blocks is negligible.
Different modes of energy saving were tested, the principle of suspending individual blocks of the system depending on the desired time of activity (see Tab.2).

The whole period of one conversion was divided into 5 phases:

Phase 1 = Measure temperature
Phase 2 = Measure acceleration
Phase 3 = Data processing
Phase 4 = Sending data
Phase 5 = Waiting for next measure

Tab. 2: Working modes

Parts	*Ph1*	*Ph2*	*Ph3*	*Ph4*	*Ph5*
RTC	A	A	A	A	A
µC	A	A	A	A	S
Temp.	A	S	S	S	S
Acceler.	S	A	S	S	S
BTE LE	S	S	S	A	S

S ~ sleep mode, A ~ active mode

The consumption of whole measure chain is shown in Table 3.We can see a big difference between full on and sleep mode. With purely digital peripherals we get even lower values.

Tab. 3: Complex consumption

Active parts	*Connecteds*	*Active*	*Idle*
All	2,9 mA	2 mA	0.9 mA

The device (see Fig.3) consists of one mainboard with central microcontroller and accelerometer, temperature sensor, Bluetooth module and storage capacitor. The Peltier cell is connected externally and allows change in size and power.

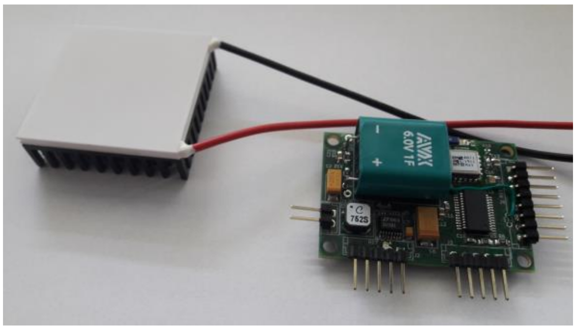

Fig.3 IoT node for temperature and movement monitoring for medical purposes

CONCLUSIONS

Testing the energy harvester using the Peltier cell and its consumption of the proposed low power application has shown that the process of harvesting of energy from one Peltier cell is not able to supply enough electrical energy for the application used.
The solution is to power the application from the preloaded battery/supercapacitor, which is charged from the harvester and thus prolongs the operating time of the device.

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